Appendix A

Experimental Setup and Use of Software

Electrodes are placed in a straight line with a constant spacing. In instances where the ground was too hard for easy insertion of the electrodes, a rubber mallet was used. Without the assistance of this aid, in some cases the stakes could not be successfully inserted into the ground. The mallet also allowed the stakes a vertical insertion with minimal side-to-side deviation that often occurred when trying to insert them by hand. Once the electrodes were pushed past the hard surface, the electrodes would typically make a good contact with the ground.

The Syscal KID is placed in between electrodes 12 and 13. The end of the cable next to electrode 12 is plugged into the slot labeled 1-12. The end of the other cable next to electrode 13 is plugged into the Syscal KID slot labeled 13-24. Plugging the cable for electrodes 1-12 into the slot labeled 13-24 and plugging the cable for electrodes 13-24 into the slot labeled 1-12 switches the direction of the survey. For example, doing this would cause electrode 1 to become electrode 24 and electrode 2 to become electrode 23. Since the cables are bi-directional, connecting the cables so that the directions are switched can easily happen. It is important to note which electrode was electrode 1 and which was electrode 24, because this dictates the direction into which the Wenner array will be activated. Switching the cables would cause any model to show the mirror image of the actual subsurface conditions.

A filename is selected for the survey before any other parameters are

entered. For this thesis, we used the nomenclature of starting the filename with the month of the experiment. For single digit months, the filename began with a 0. The next two numbers would be the numerical day of the month of the experiment. Again, if this was a single digit, then it would begin with a 0. The following two digits were the location number followed by an A if it was the first survey at that location that day, B if it was second survey, C if it was the third survey, etc.. For example, for a survey that was conducted on March 5th, which was the second survey at location 3 that day, the filename would read: 030503B. For the first survey on August 10th at location 6, the filename would read: 081006A.

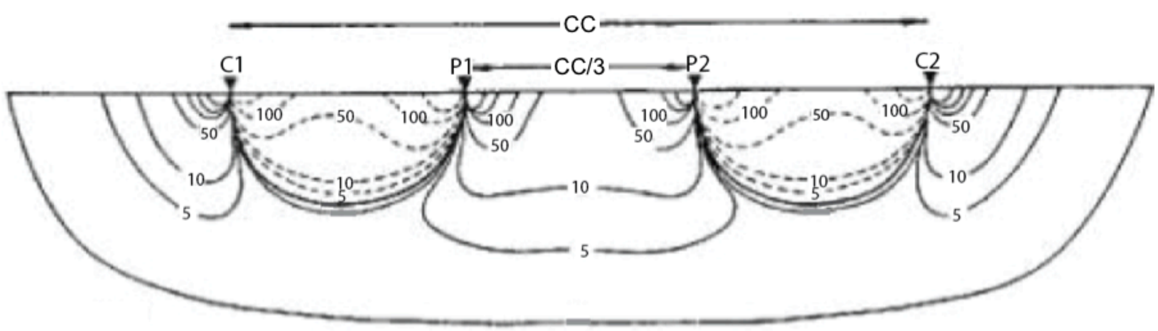
After a filename is chosen, the stack minimum, the stack maximum, and the q maximum is set. The Syscal KID performs each measurement between a particular set of electrodes multiple times before moving on to another set of electrodes. The q maximum was the quality factor, or the maximum allowable standard deviation of voltage over current (V/I) in %. If this value has a standard deviation less than the q maximum, the survey moves on to the next set of electrodes, if the minimum number of stacked measurements has been reached. The stack minimum is the minimum number of measurements that must be performed for a configuration of electrodes. The stack maximum is the maximum number of measurements that can be performed before moving on to the next set of electrodes. The user can choose individual values for each of the desired parameters. When the potential is measured across the electrodes:

-if $q < q$ max and stack number > stack minimum, then the stacking

process stops

-if q > q max then the stacking process will continue until q < q max or until the maximum number of stacks is reached (stack max)

After the stack minimum, the stack maximum, and the q maximum have been set, the type of a survey is selected as well as the electrode spacing. A Wenner PRF is selected and the survey electrode spacing (CC/3) is set. When a survey is conducted, 4 electrodes are used for each measurement (Appendix A-1). The term CC refers to the distance between the two current electrodes. Dividing this distance by 3 gives the electrode spacing (a) for the measurement. The survey spacing is entered into the Syscal KID in units of meters, so that, when the data is plotted by the software, the pseudosection displays the depth and distance in units of meters.



Appendix A-1. Current flow between two source electrodes and two receiver electrodes in a Wenner electrode array. As current flows between electrode C1 and C2, current is dissipated in all directions. This current is measured at electrodes P1 and P2. The term CC refers to the distance between the two current electrodes (C1 and C2). Dividing this distance by 3 yields the electrode spacing. Adapted from Samsudin (n.d.).

The level is then set for the survey (Appendix A-2). As a survey is conducted, measurements are first taken with the minimum electrode spacing (a). This is the CC/3 distance or how far the electrodes are spaced apart.

Measurements are then taken for 2 times the electrode spacing (2a), 3 times the electrode spacing (3a), and this continues until all combinations have been used. The level denotes when to stop increasing the electrode configuration spacing.

If level 7 (the maximum) is selected, the sequence of the first few measurements is:

Electrode spacing = a 1 2 3 4

Electrode spacing = 2a 1 3 5 7

Electrode spacing = 3a 1 4 7 10

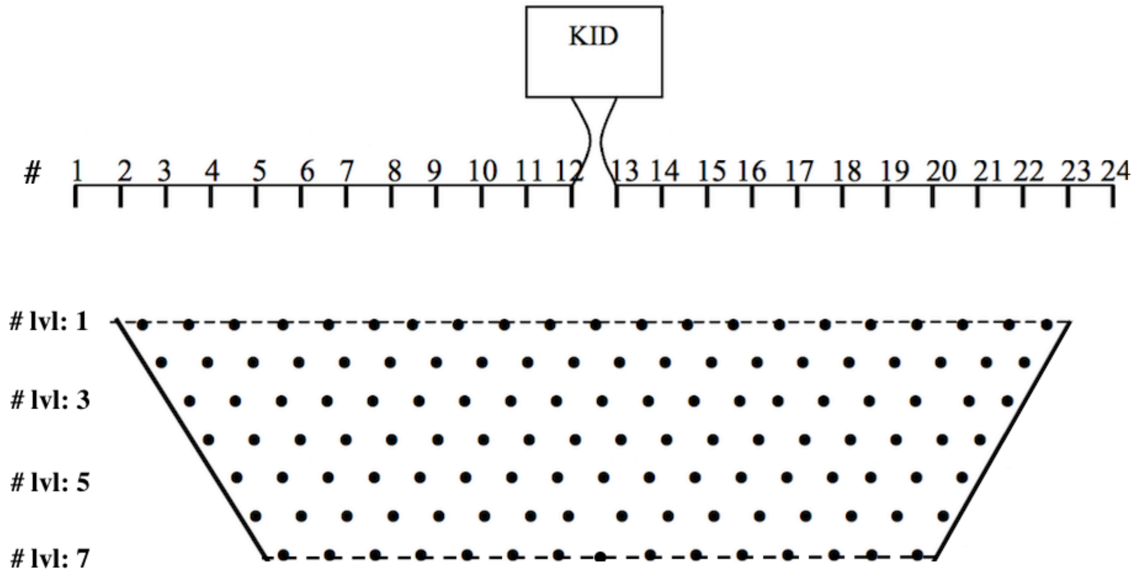
Electrode spacing = 4a 1 5 9 13

Electrode spacing = 5a 1 6 11 16

Electrode spacing = 6a 1 7 13 19

Electrode spacing = 7a 1 8 15 22

With 24 electrodes, 7 is the maximum level that can be performed. Setting the Syscal KID to a level lower than its maximum level will not allow deeper structure to be seen.



Appendix A-2. A Wenner electrode array with 24 electrodes. For a survey with 24 electrodes, 7 depth levels can be performed. Adapted from IRIS (2001).

The user can then choose to start the survey. Running the survey with maximum level should take about 20-30 minutes depending on how many times the survey needs to measure using the same electrode configuration before moving on to the next set of survey points. While this is done, the exact placement of the survey line can be noted.

The GPS coordinates were recorded utilizing either decimal degrees or in UTM format and in NAD27 or WGS84 using hand held GPS units. The GPS points were converted to WGS84 format using an internet GPS converter (http://www.cohp.org/coordinate_transformations.html). This allows easy input into Google Earth. Distances to landmarks that cannot move such as sidewalks, light pools, streets, fire hydrants, etc. were also recorded. Measurements of the exact location of the survey relative to surrounding landmarks were made. This allowed for accurate placement of each of the survey lines in case GPS

measurements were inaccurate.

Software Usage

The Prosys II software can be downloaded from the IRIS website free of charge (http://www.iris-instruments.com/Support/support.html). Version 03.07.04 was used throughout processing, and specific workflow notes pertain to it. After downloading the data from the resistivity unit utilizing the Prosys II software is complete, the data is saved as a bin file. The bin file can be opened by clicking on the bin file and setting the default program as the Prosys II software. It can also be opened by opening the Prosys II software, then going to file, hitting open (the first option), and selecting your desired bin file from the directory (Prosys II→file→open).

Processing

Once the desired data file has been opened, the Prosys II software can be used to process the data. When using the Syscal KID switcher unit, it was found that measurements with 3 times the electrode spacing had unusually high deviations. The default sequence that each of the measurements is taken in is the reason for this deviation. Part of the measurement sequence for the switcher is:

Electrode spacing = a 1 2 3 4

Electrode spacing = 2a 1 3 5 7

Electrode spacing = 3a 1 4 7 10

Electrode spacing = 4a 1 5 9 13

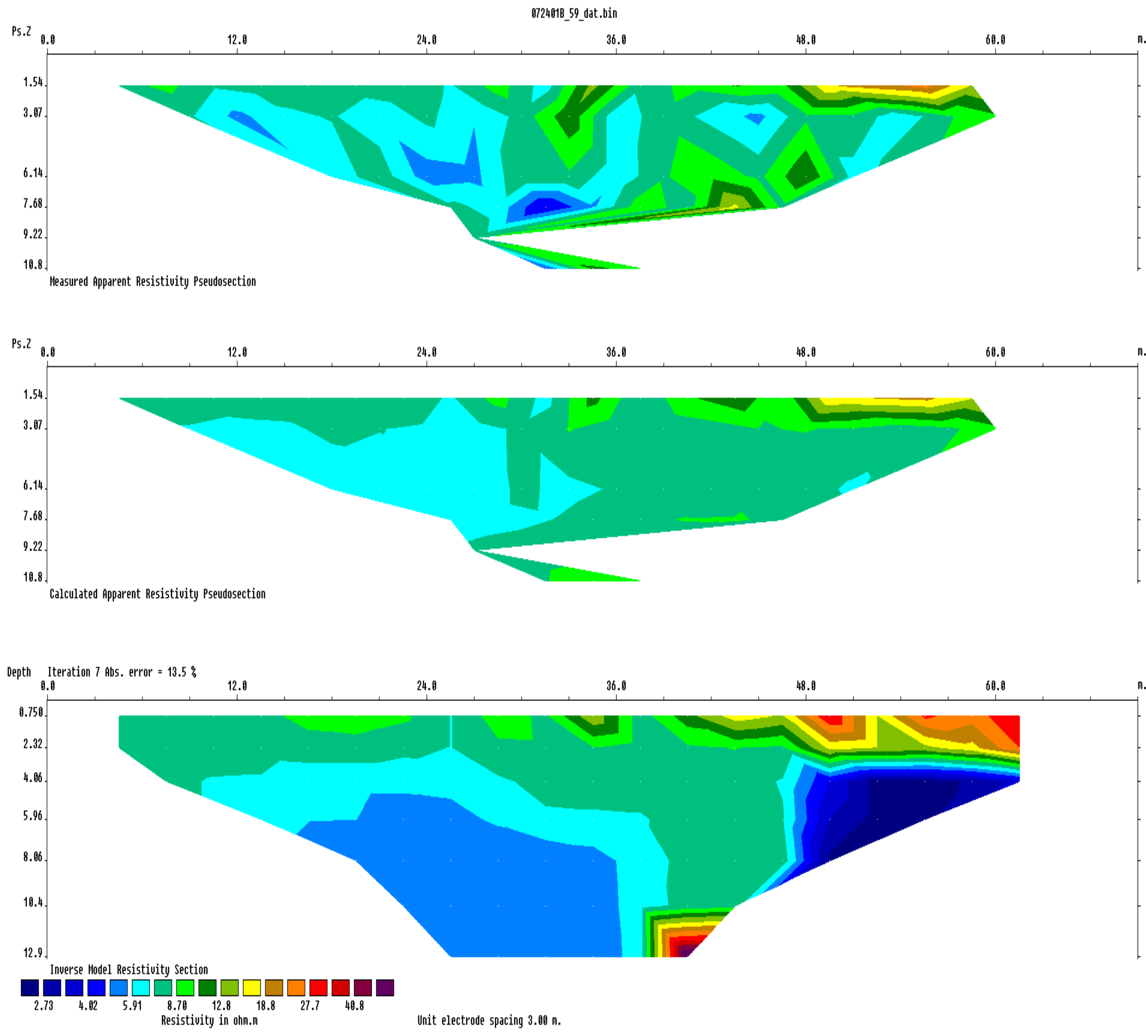
The middle two electrodes serve as the measurement electrodes while the

first and last electrode are the source electrodes. When the sequence switches from an electrode spacing of 2a to an electrode spacing of 3a, an electrode that was previously a source electrode becomes a receiver electrode. When this switch happens, residual current is still present on the old source electrode. This causes a deviation during the measurement. This deviation only occurs during this particular part of the sequence, since this is the only occurrence of switching an electrode from source to receiver in subsequent measurements. Due to this systematic error, it was found that removing the measurements with 3a electrode spacing significantly improved the results of the inversions, as would be the case for any measurement with large error.

The software has a built in filter that removes measurements that have a resistivity (ρ) lower than 0.100000001490116, any resistivity (ρ) value greater than 20000, or any data point that has a standard deviation greater than 20. This filter aids in processing, and removes bad data points. The automatic filter can be accessed by going to processing, then selecting automatic filter (Processing→Automatic Filtering). The removed points will be unchecked from the selection, and any removed points will have a white background in the software spreadsheet, while the points that are still selected will have a red background.

Alternatively, a data point can be removed manually by unchecking the data point in the software. This may be desired for many different reasons, but is most commonly associated with a measurement that has an anomalously high standard deviation. It is important to deselect these data points at this stage of

the processing, since it will be more difficult to remove these data points at a later stage. The corresponding region of the calculated apparent resistivity pseudosection will be missing and shown as empty space (Appendix A-3). Care must be taken to not remove too many data points from the data set or it will adversely affect the inversion model. Measurements that had high standard deviations and were removed from the inversion were commonly associated with features that could cause serious errors such as metal fences, fire hydrants, and other infrastructure. However, discretion must be used to ensure that the user is not removing valid data points.



Appendix A-3. An inversion from RES2DINV for survey 072401B at survey site 01. This dataset had 25 points removed, as can be seen in the measured apparent resistivity pseudosection. This results in a zone of missing data that can be seen as a cut across the measured apparent resistivity pseudosection (top).

Topography

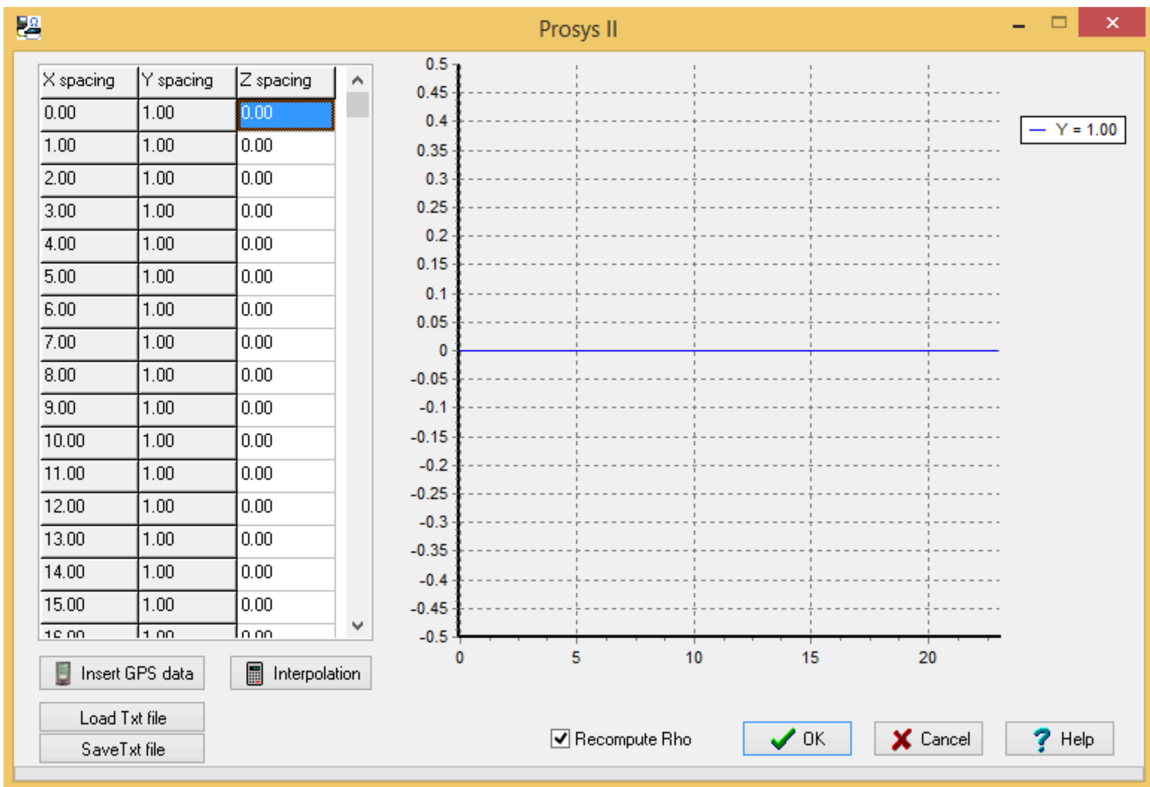
Topography in the survey locations can negatively affect an inversion if it is not properly taken into account. Topography can be inserted into the data set when using the Prosys II software. When in the field, each electrode's position must be recorded if there is a change in topography. Topography needs to be inserted when the electrodes are not on a consistent slope (Appendix A-4).

The Prosys II software can incorporate topography variations by characterizing each electrode's position in an XYZ format. By default, the X field is the spacing between each of the electrodes. Since the terrain is not flat, an option is selected to indicate that this is the distance across the surface and not true horizontal distance. The Y field was left blank since the electrodes were spaced in straight line with relation to each other. The Z field was populated with the vertical position of each electrode in relation to a reference electrode. For survey 063003A, the reference electrode was chosen to be the first electrode.

Appendix A-4. Survey 050903A at location 3. The inconsistent elevation causes variations in in the resistivity model if the topography is not taken into account.

The dataset must be transformed into an XYZ space before topography

can be entered. This is done by going to processing, then selecting the transform spacing XYZ option (Processing→Transform spacing XYZ). Each of the selected data sets in the Prosys II software will have a red background. The user can now insert topography by going to the processing tab and selecting Insert topography (Processing→Insert topography). The data points will then be shown with an option to change the Z spacing (elevation) of each of the data points (Appendix A-5).



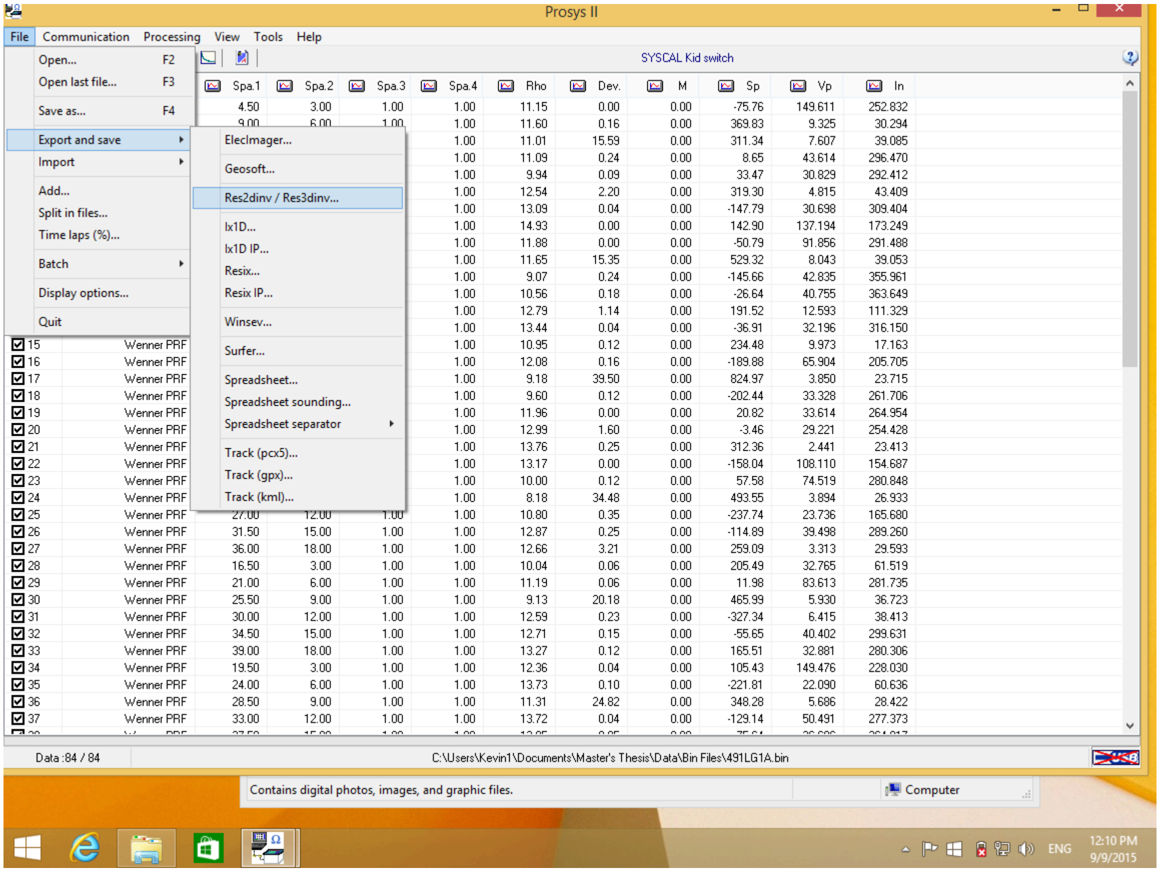
Appendix A-5. Topography insertion screen on the Prosys II software. When inserting topography data, the position of each electrode is transformed into XYZ space. Once this is established, elevation positions (Z) can be entered into the data file.

The X position and the Y position in the XYZ position window will remain fixed and already be filled out. When conducting a Wenner array, each electrode

will be separated by the same distance, thus each position is known. The Y position will be a constant value of 1. Since a Wenner array is conducted on a straight line, each electrode will have the same Y position. The Z position is the vertical position of each electrode in relation to a reference electrode. Typically choosing the electrode with the lowest vertical position as the reference simplifies input, but any reference electrode can be used. When entering the Z position for each electrode, it is important to enter the position in the same units as you used for the spacing. When you are done entering the topography, select the ok button on the bottom of the screen and you will be returned to the original processing screen.

Exporting

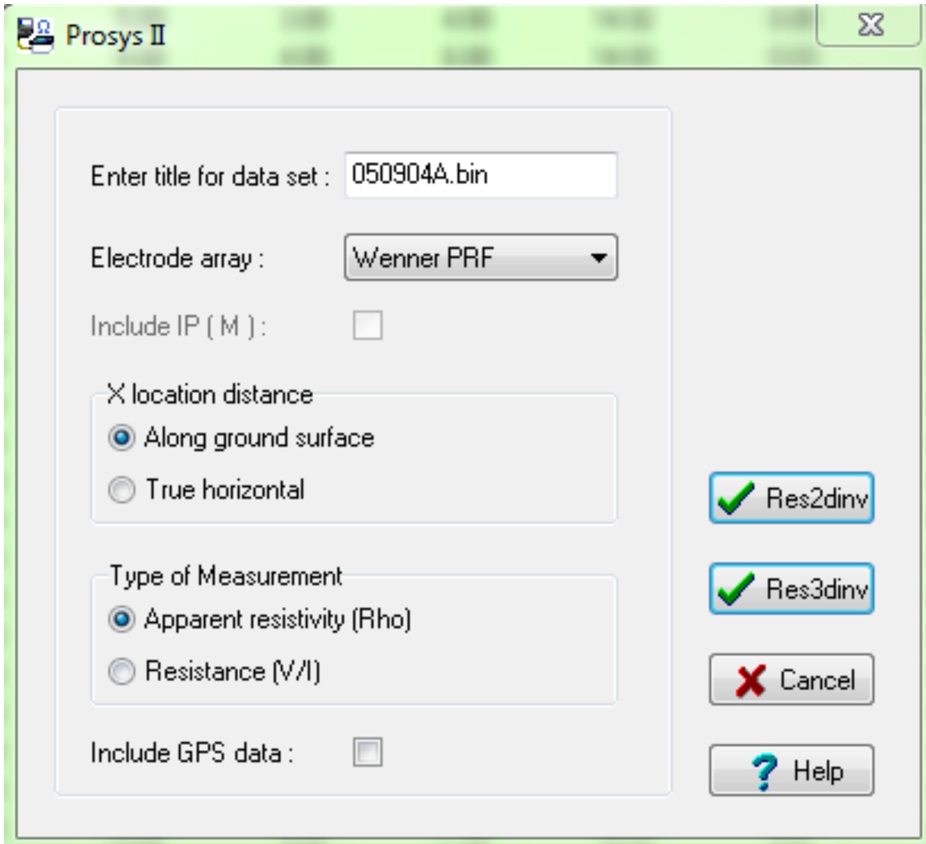
Once the user is done processing the data, the data can be exported into a dat-format file that can be read by Geotomo's RES2DINV software. The user goes to File, Export and save, and then selects RES2DINV/RES3DINV… (File→Export and save→RES2DINV/RES3DINV…) (Appendix A-6).



Appendix A-6. Topography insertion screen on the Prosys II software. When inserting topography data, the position of each electrode is transformed into XYZ space. Once this is established, elevation positions (Z) can be placed into the data file.

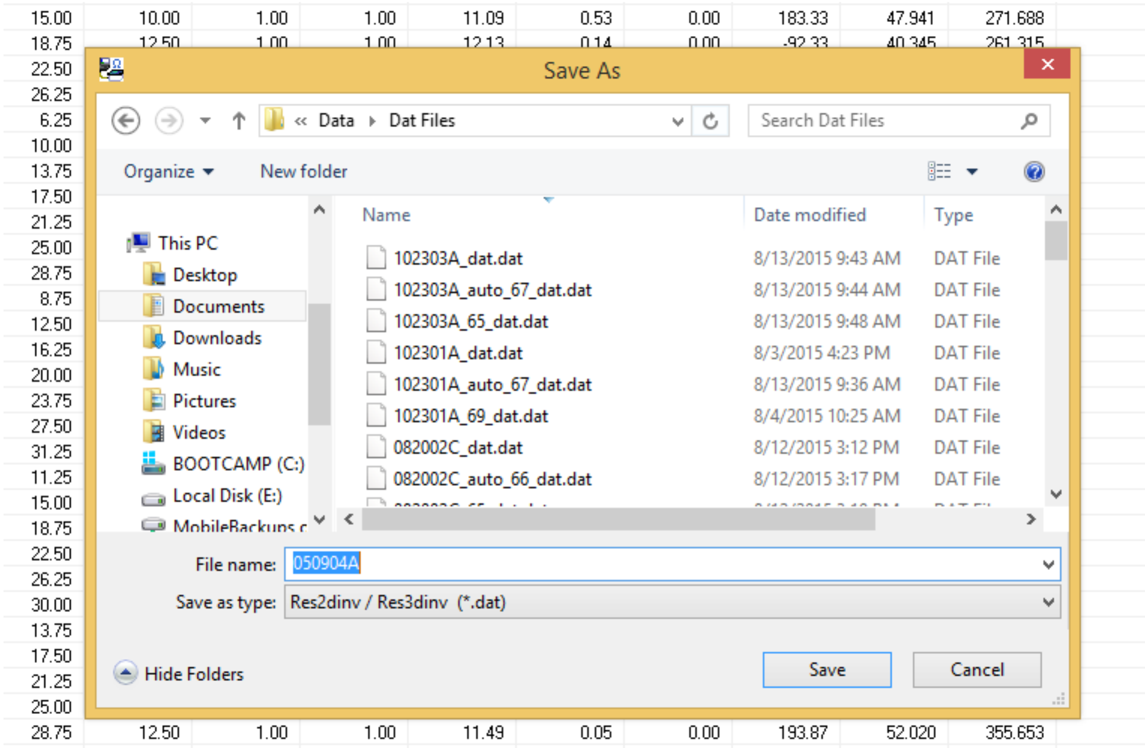
A window will pop up giving the user a few options (Appendix A-7). It allows the user to save the data as a bin file in a Wenner array. The X location distance can be selected to be either true horizontal distance or along the ground surface. The difference between true horizontal and along the ground surface is only significant when topography is introduced. Separating the electrodes with a tape measure resting along the surface results in the spacing along the ground surface. True horizontal distance is when the electrodes are spaced the same distance apart in a horizontal plane regardless of topography. The type of

measurement selected is Apparent resistivity (Rho).



Appendix A-7. The Prosys II window asking the user to export the file for use in RES2DINV.

Selecting the RES2DINV box will save the bin file and then allow the user to save the data as a dat file. The user can choose a save destination for the dat file (Appendix A-8) and the location of the dat file should be noted. The dat file is used as input into the RES2DINV software when conducting the inversion.



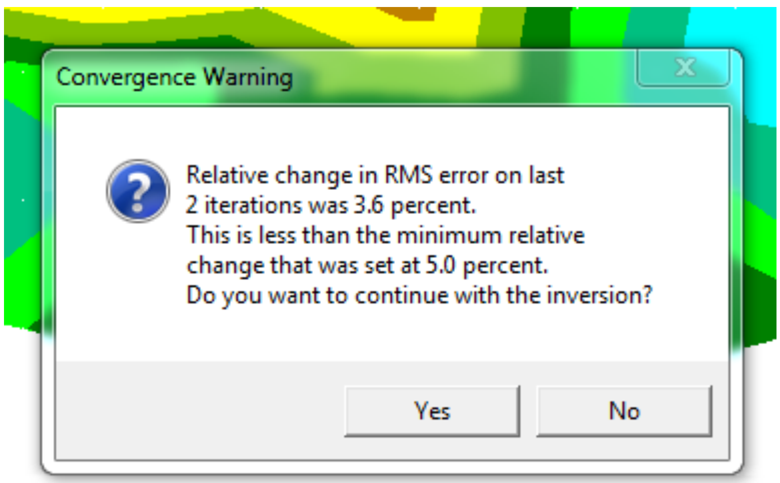
Appendix A-8. The window asking where to save the file that the user will use for RES2DINV. It is important to note where the file is located because the file will need to be read to carry out the inversion.

Carrying Out the Inversion

The RES2DINV software must be open on the computer. The dat file created using the Prosys II software must be transferred to the computer running RES2DINV. The file can be read from a directory on the computer or read from a flash drive. Reading of the dat file is accomplished by going to File and selecting Read data file (File→Read data file). If done correctly, a message will appear indicating that the reading of the data file has completed. Once the data file has successfully been read, the user can carry out the inversion by going to inversion and selecting Carry out inversion (Inversion→Carry out inversion). Before the inversion can be run, a file must be saved for the inversion results as an inv file.

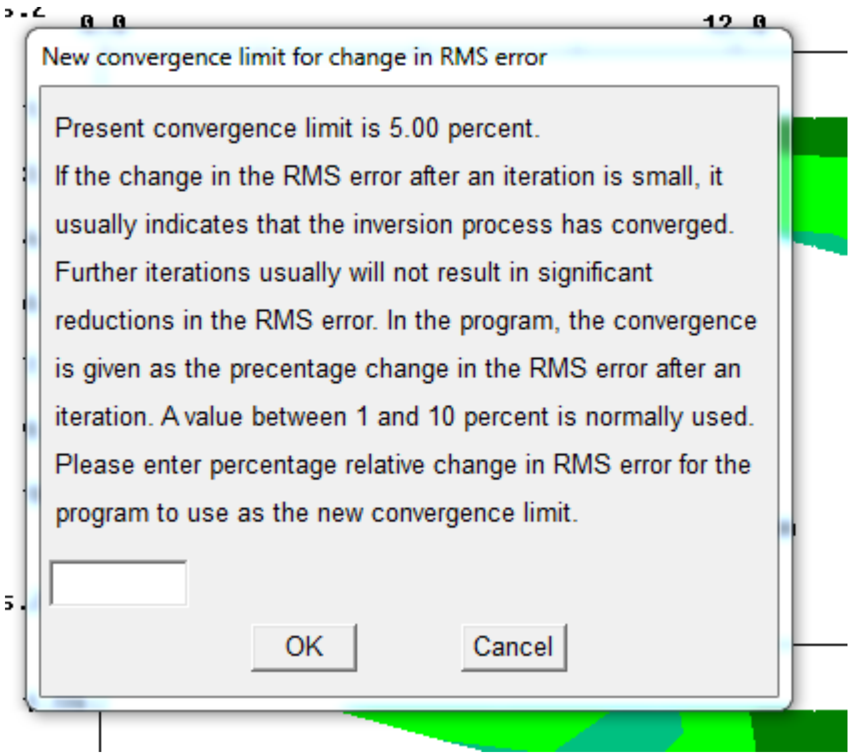
Once a file has been saved, the inversion will run.

The inversion will create a model of subsurface resistivity that varies laterally and with depth. The model will continue to iterate until the model is no longer improving by at least 5% in Root Mean Square (RMS) error from one iteration to the next. This will continue until the maximum number of iterations is reached or until the improvement in the model is no longer significant (Appendix A-9).



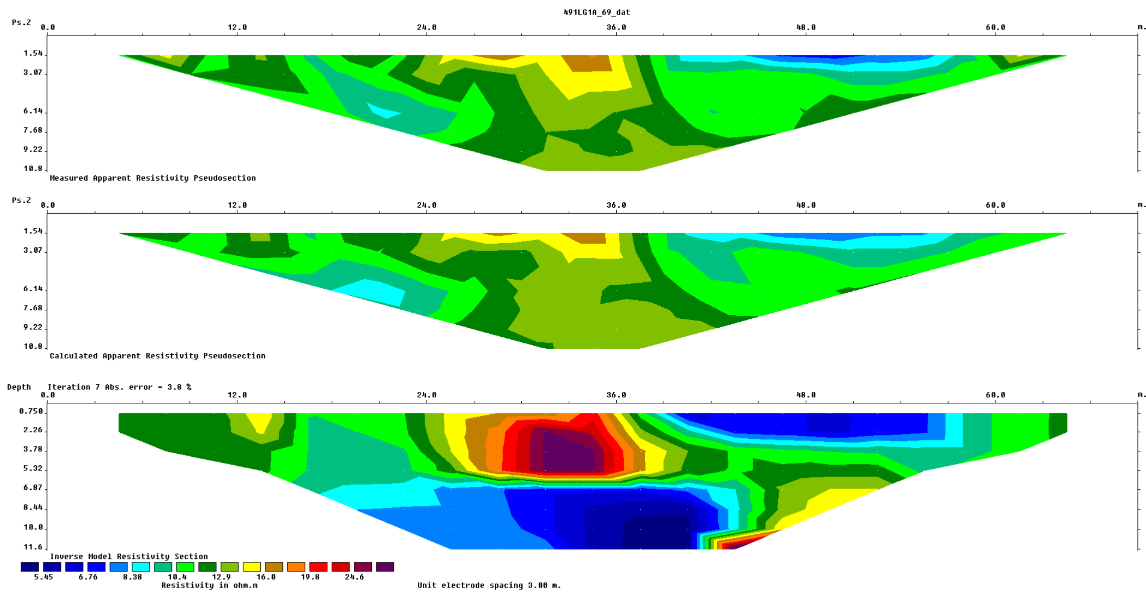
Appendix A-9. The window showing that the model is no longer improving by more than an RMS Error of 5%.

The user can decide if they want to set a lower percentage for the threshold for iterations to stop, or they can decide to stop the iterations now. If yes is selected, a threshold lower than 5% must be selected (Appendix A-10). Iterations will continue until the model is no longer improving by the new minimum threshold, or the maximum number of iterations is reached.



Appendix A-10. The display window asking if a new convergence limit would like to be set. When the model's RMS Error is no longer improving by more than 5%, the inversion stops. The user can choose to set the convergence limit lower at the expense of more processing time.

Once the user has decided to stop the iterations, the pseudosection is displayed (Appendix A-11). This final screen shows the measured apparent resistivity pseudosection, the calculated apparent resistivity pseudosection, and the inverse model resistivity pseudosection.



Appendix A-11. A typical display when an inversion is made using RES2DINV.

Resistivity Contour Intervals

Resistivity contour intervals can be manually changed from the default logarithmic contour intervals. Once the user is finished carrying out the inversion, the user goes to the Display Sections Window (Display→Show Inversion Results). The user then opens the display data model and sections window (Display sections→Model display→Display data and model sections). A window will appear asking how many iterations the user wants to use. The user cannot select more iterations than were performed when carrying out the inversion. For reference, the window indicates how many iterations were performed during the inversion. For example, if it took 11 iterations for the model before the model was no longer improving by 5% or more, than the user can select a maximum of 11 iterations. The default setting is logarithmic contour intervals, but the user can choose to select linear contour intervals, user defined linear contour intervals, user defined logarithmic contour intervals, user defined contour intervals, or the

user can choose to read contour values from a file. When user defined contour intervals are chosen, they can be saved as a val file. The option to read contour values from a file allows the user to read these resistivity contour values that were previously saved into a file.

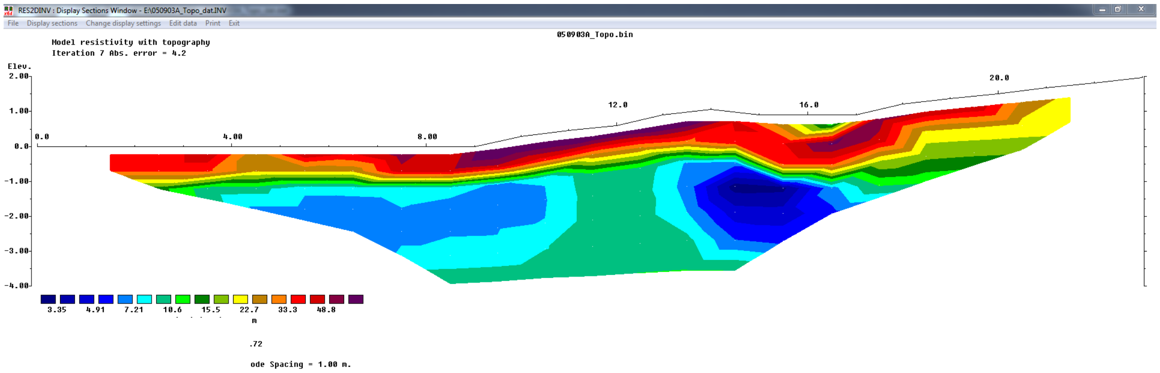
Inclusion of Topography

Carrying out an inversion that include the profile topography involves many of the same steps as inverting data that does not include topography, but a few extra steps are involved. First the user reads the data file by following the same steps as a normal inversion. This is done by going to File and selecting Read data file (File→Read data file). Then the user selects the desired dat file. The software will notify the user when the reading of the data file is complete. Next, the user goes to the Inversion drop down menu and selects Carry out inversion (Inversion→Carry out inversion). The inversion will continue until the model is no longer improving by 5% or more from one iteration to the next (Appendix A-10). The user can choose to stop the iterations there or add additional iterations. The software requires an inv file to be saved and the user can select where to save the inv file. The default file name will be the same as the data file being read with an inv extension.

Checking the topography can be done by going to the Topography Options menu and selecting Display topography (Topography Options→Display topography) (Appendix A-12). If this step is taken, the data file must be read and the inversion carried out again.

Appendix A-12. Displayed Topography section. When checking the file for topography, a window will appear showing the topography the user entered in the Prosys II software.

The user then goes to Display menu and selects Show inversion results to continue onto the Display Sections Window (Display→Show inversion results). To get a model that includes the topography, the user goes to the Display sections menu, selects Model display, and then selects Include topography in model display (Display sections→Model display→Include topography in model display). A window will appear asking how many iterations the user wants to use. Next, the user can select the type of contour intervals of resistivity the user wants to use for the inversion model. A detailed explanation of the iteration window and the contour interval window can be found in the section titled Resistivity Contour Intervals. An inversion model that includes topography will then be displayed with the indicated contour intervals (Appendix A-13).



Appendix A-13. An inversion model displayed with topography inserted. The surface is not flat due to the topography of the surface where the survey was conducted.